

# Tackling seasonal prediction of extremes with high-res coupled models: tropical and extratropical storms

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Workshop on High-Resolution Coupling and Initialization to Improve Predictability  
and Predictions in Climate Models

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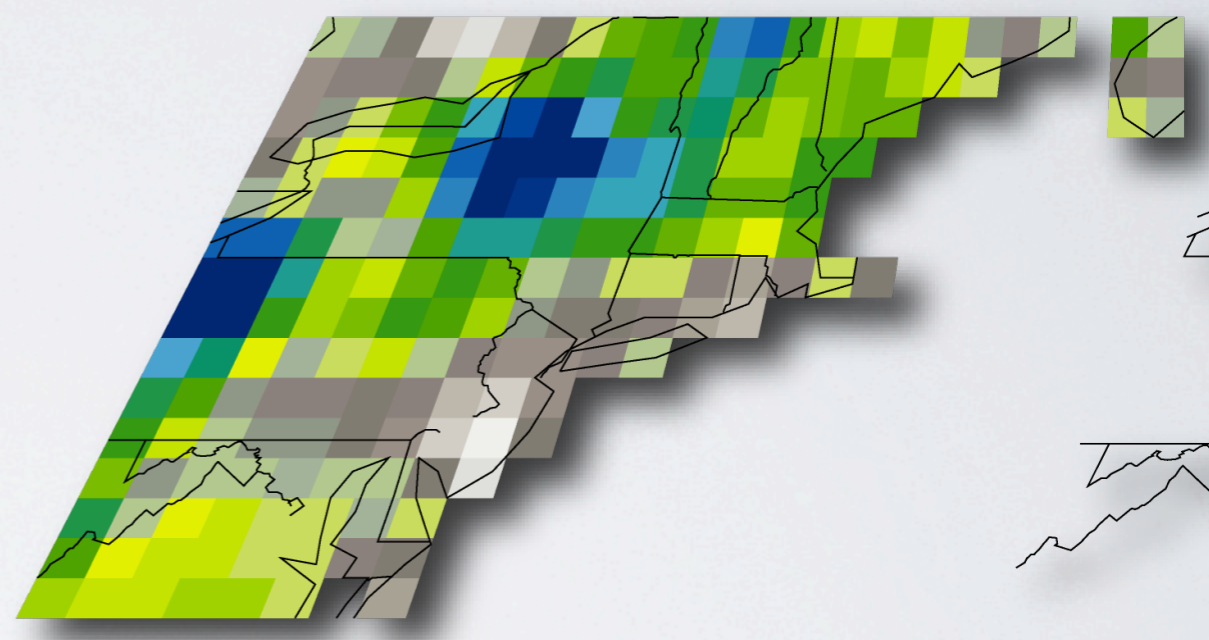
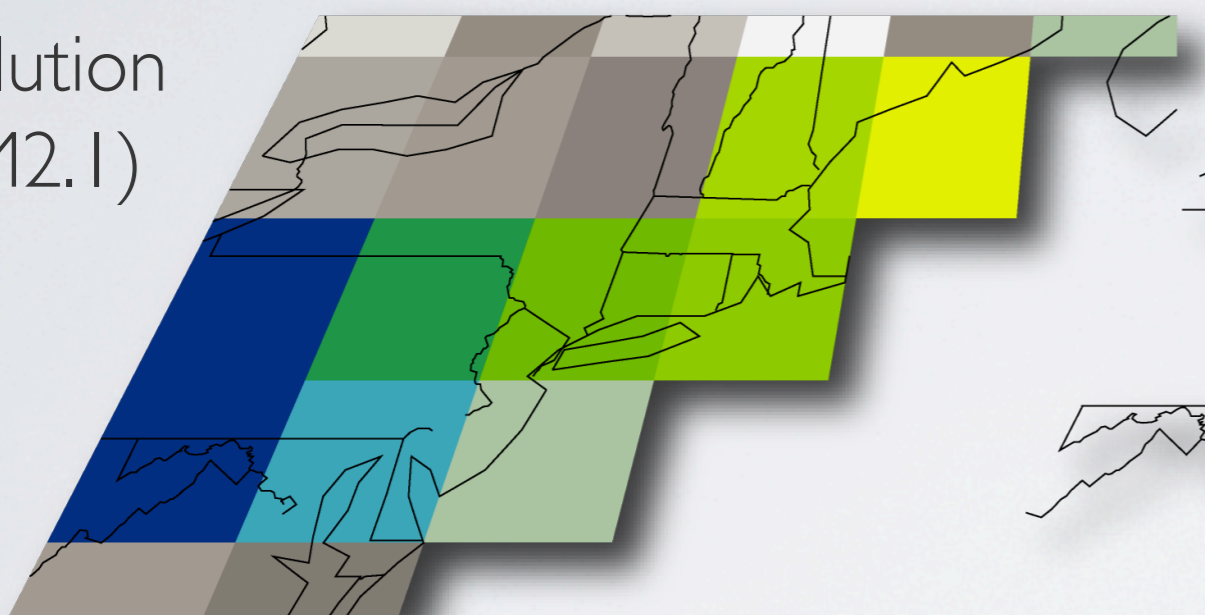
**GFDL FLOR:** Experimental high-resolution coupled seasonal to decadal prediction system

**Goal:** Build a seasonal to decadal forecasting system to:  
Yield improved forecasts of large-scale climate  
Enable forecasts of regional climate and extremes

Precipitation in Northeast USA

High resolution  
(CM2.5-FLOR)

Medium  
resolution  
(CM2.1)



*Delworth et al. (2012), Vecchi et al. (2014)*

Modified version of CM2.5 (Delworth et al. 2012):

- 50km cubed-sphere atmosphere
  - 1° ocean/sea ice (low res enables prediction work)
- ~15-18 years per day. Allows multi-century integrations  
Contributed to NMME from March 2014

Tropical cyclones (TCs) and extratropical storms (ETSs) cause weather/ climate extremes for natural disasters (winds, flooding, blizzards)

**Hypothesis:** Enhanced resolution improves simulation (fidelity) and prediction of regional climate & extremes (TCs and ETSs).

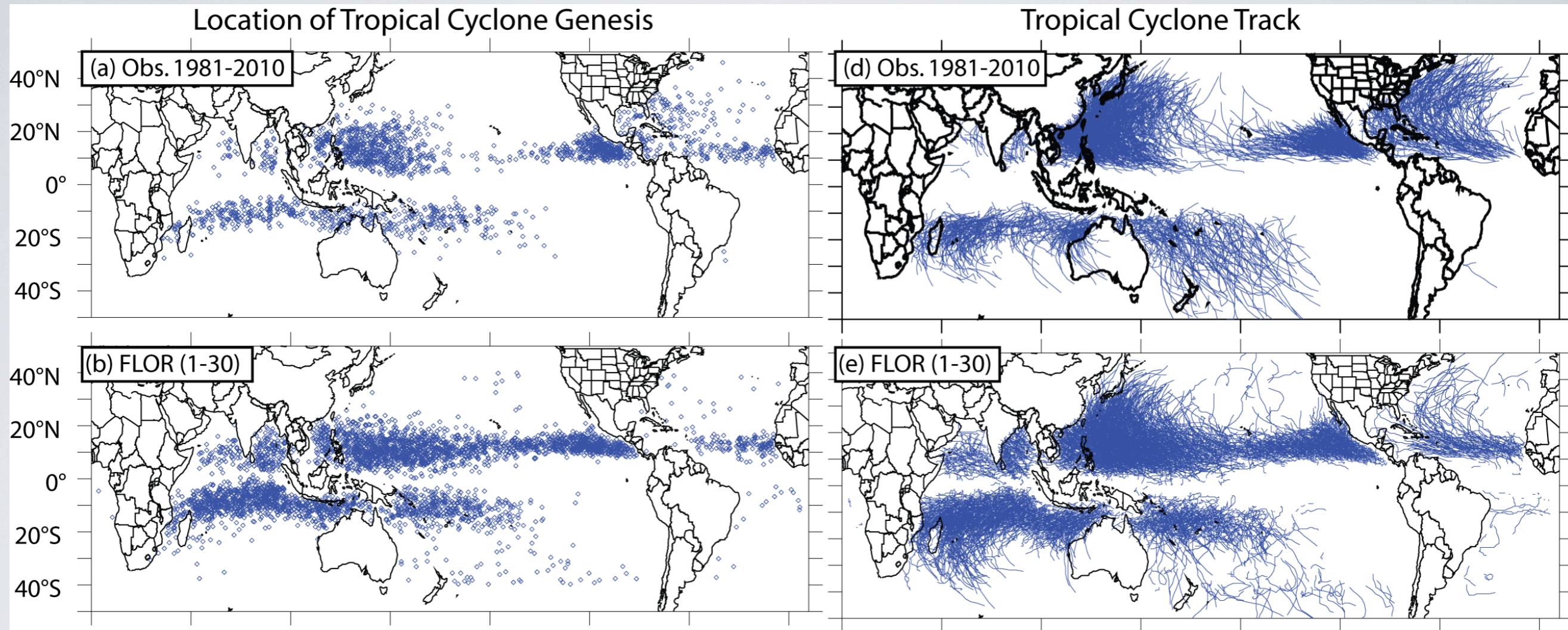
Tropical cyclones (TCs)

- GFDL-CM2.1 (~200x250km atmosphere/land, 1° ocean/sea ice): No-TC
- GFDL-FLOR (50km atmosphere/land): TC-permitting
- GFDL-HiFLOR (25km atmosphere/land): TC-category-resolving

Extratropical storms (ETSs)

- All the three models resolve ETSs
- Can we still improve ETSs with high-res models?

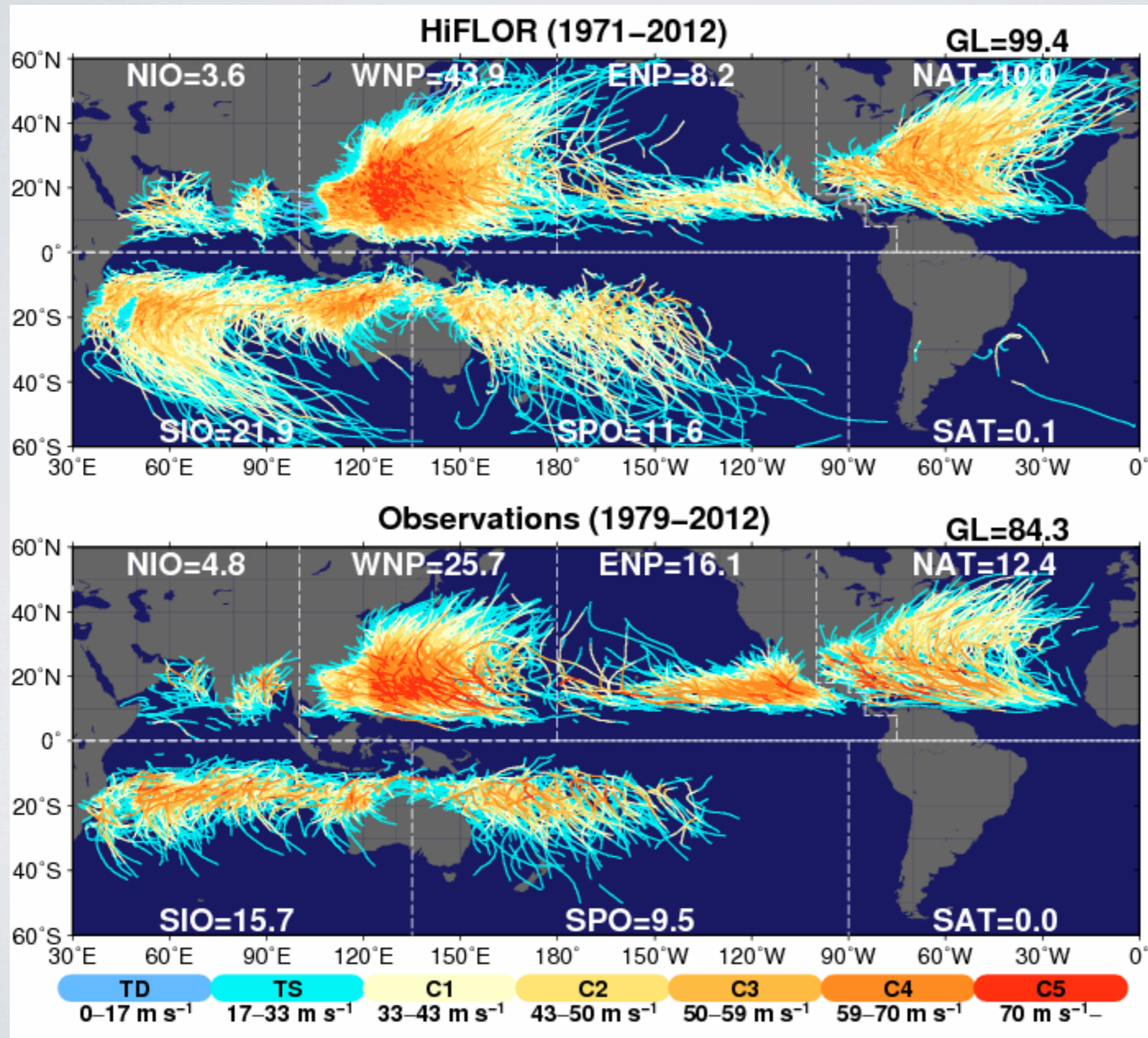
# TC tracks in FLOR decent for a coupled model



Fidelity of TCs

Vecchi et al. (2014)

HiFLOR: doubling atmospheric resolution of FLOR (cost 6x) allows us model to simulate Cat. 4-5 TCs (most destructive storms)

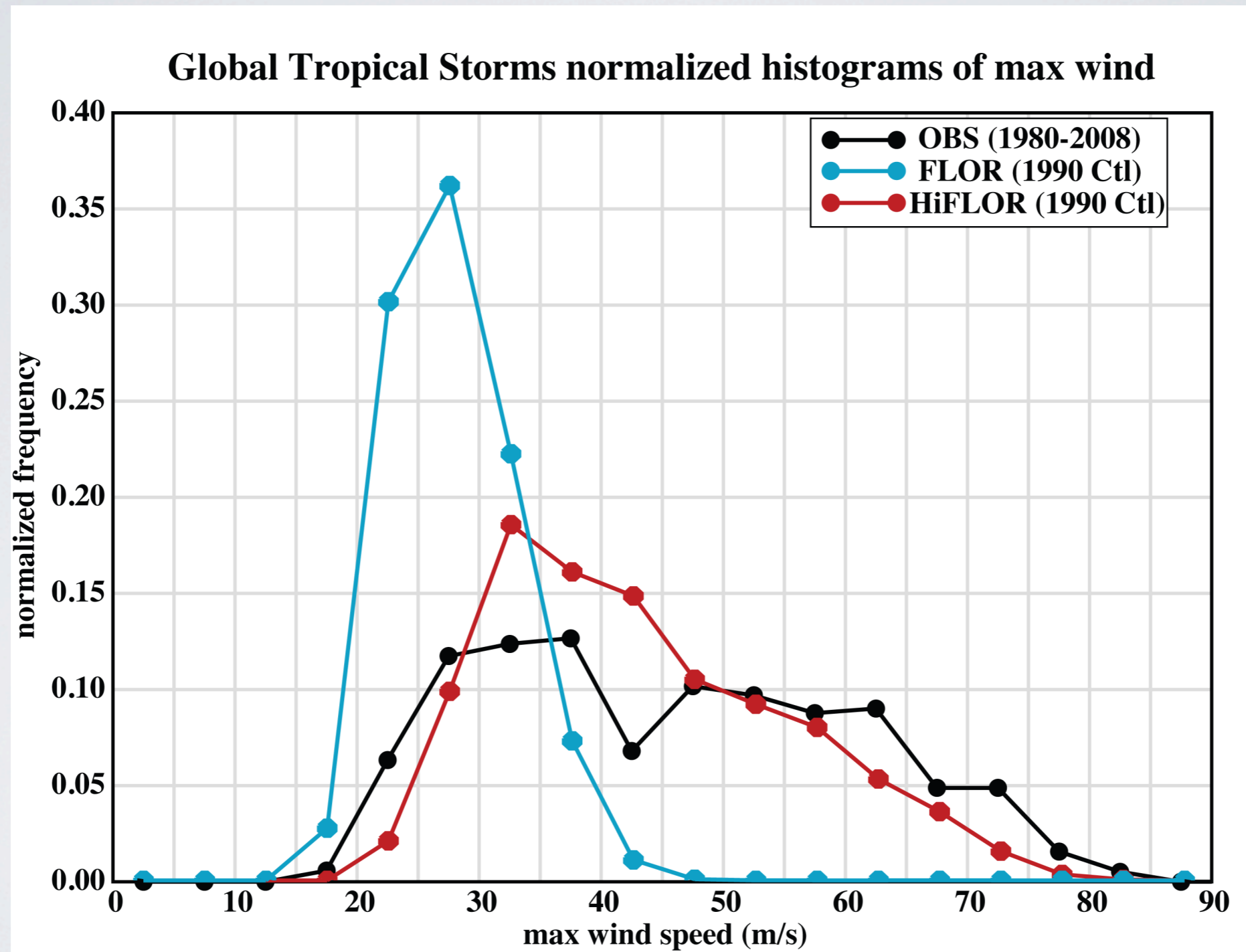


*Murakami et al. (2015)*

**Fidelity of TCs**

Most impactful hurricanes tend to be strongest.

Need prediction models that can capture them. New prototype model (“GFDL-HiFLOR”, first run May 2014) able to simulate Cat. 4-5s

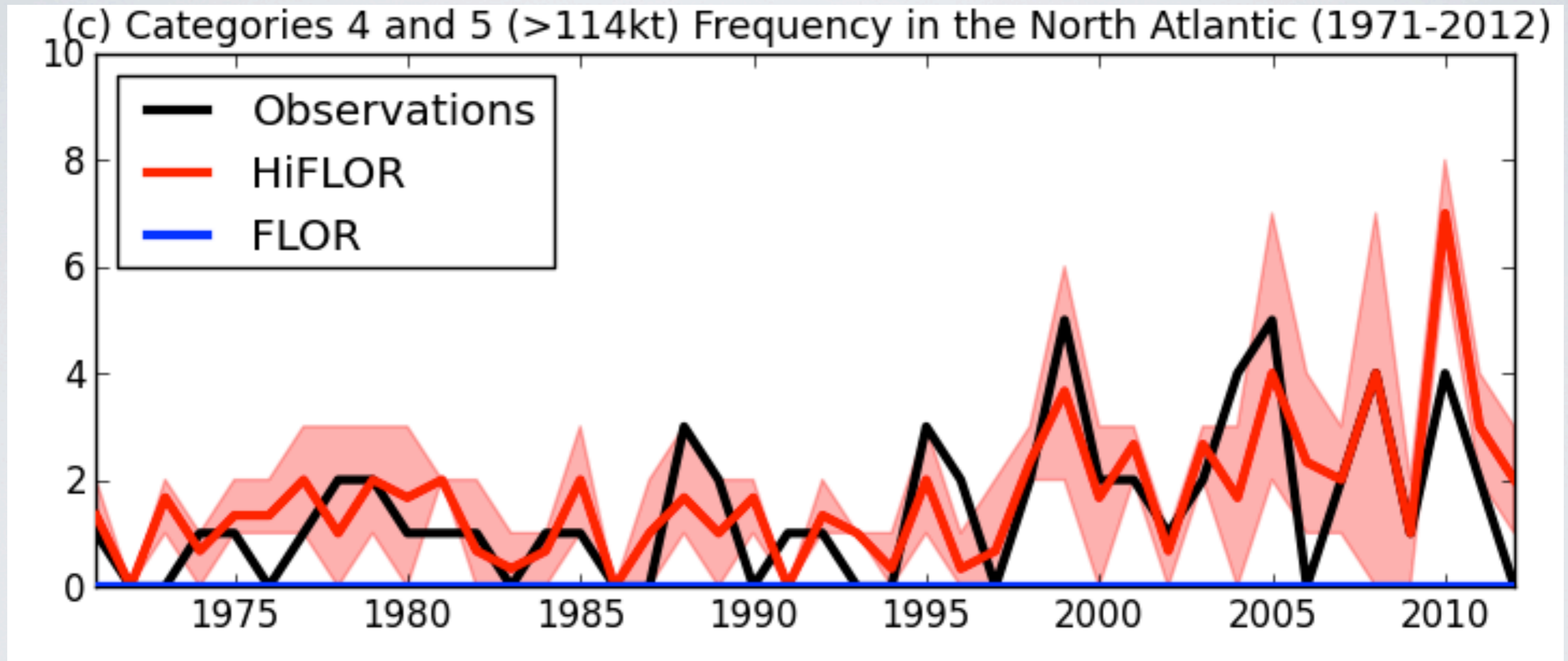


(25km FV3 atmosphere coupled to 1° MOM5)

Fidelity of TCs

*Murakami et al. (2015, J. Clim., in press)*

HiFLOR prototype NOAA-GFDL prediction model recovers  
Cat. 4-5 history...experimental predictions encouraging...

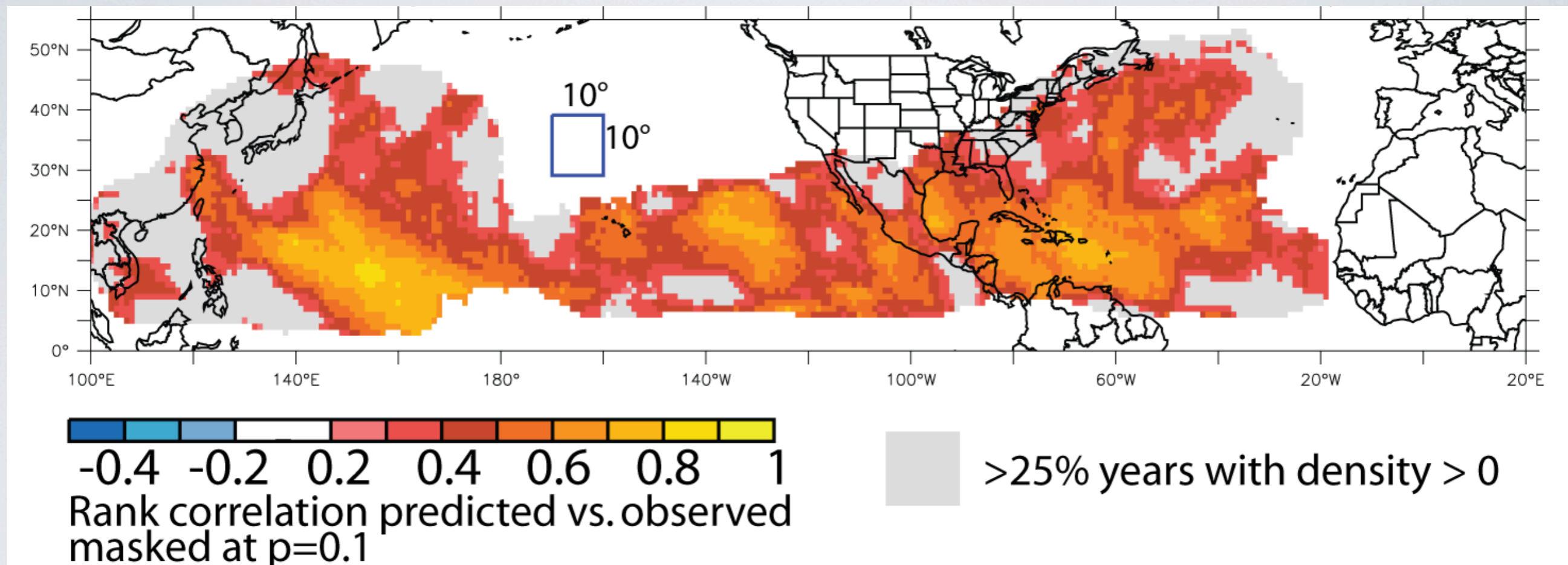


(25km FV3 atmosphere coupled to 1° MOM5)

Fidelity of TCs

# FLOR: Seasonal predictions of regional TC activity

GFDL-FLOR 1981-2012 1-July Initialized Forecasts for July-December

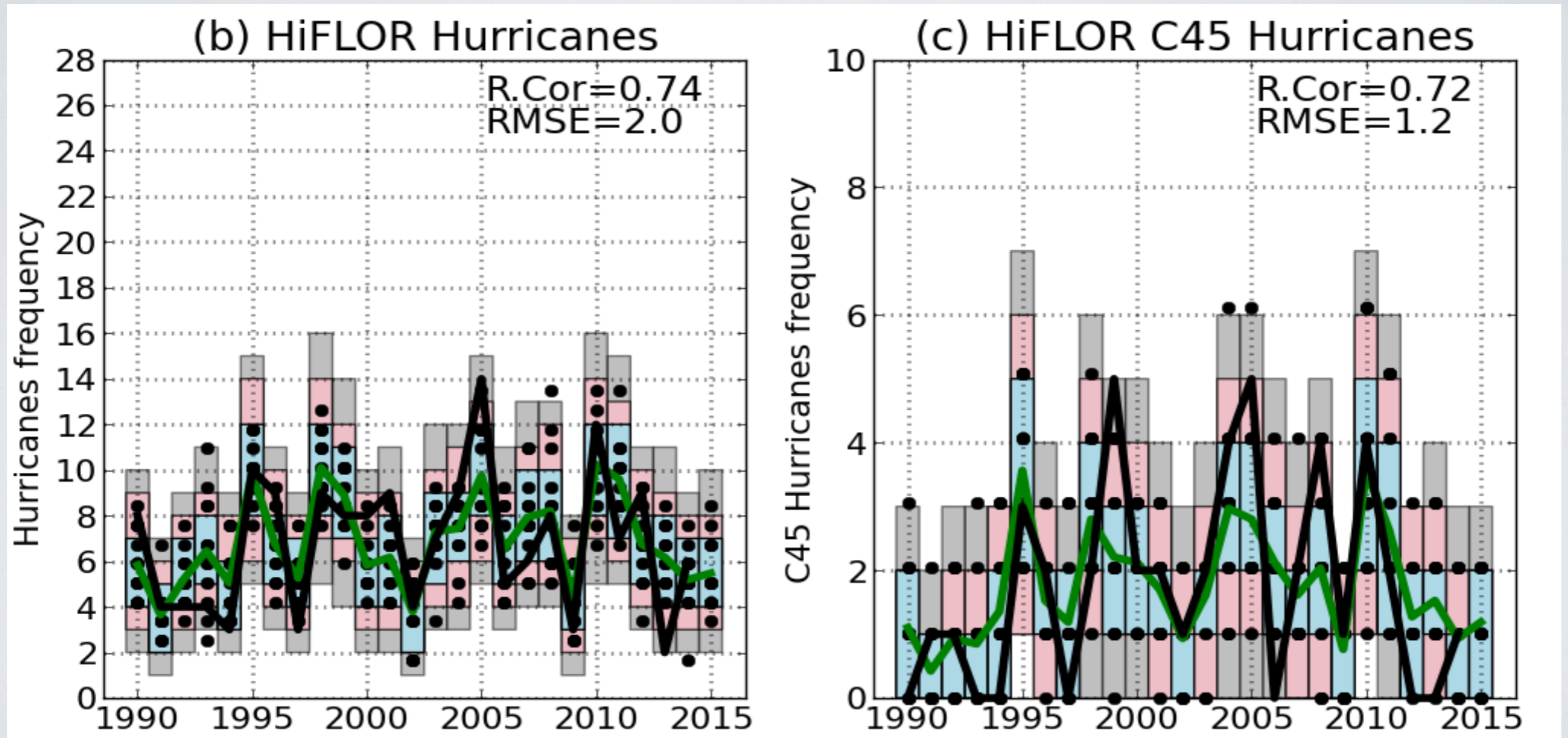


**Rank correlation:** Can experimental FLOR forecasts distinguish years with many and few storms passing within  $10^\circ \times 10^\circ$  of a point?

*Vecchi et al. (2014, J. Clim.)*

Prediction of TCs

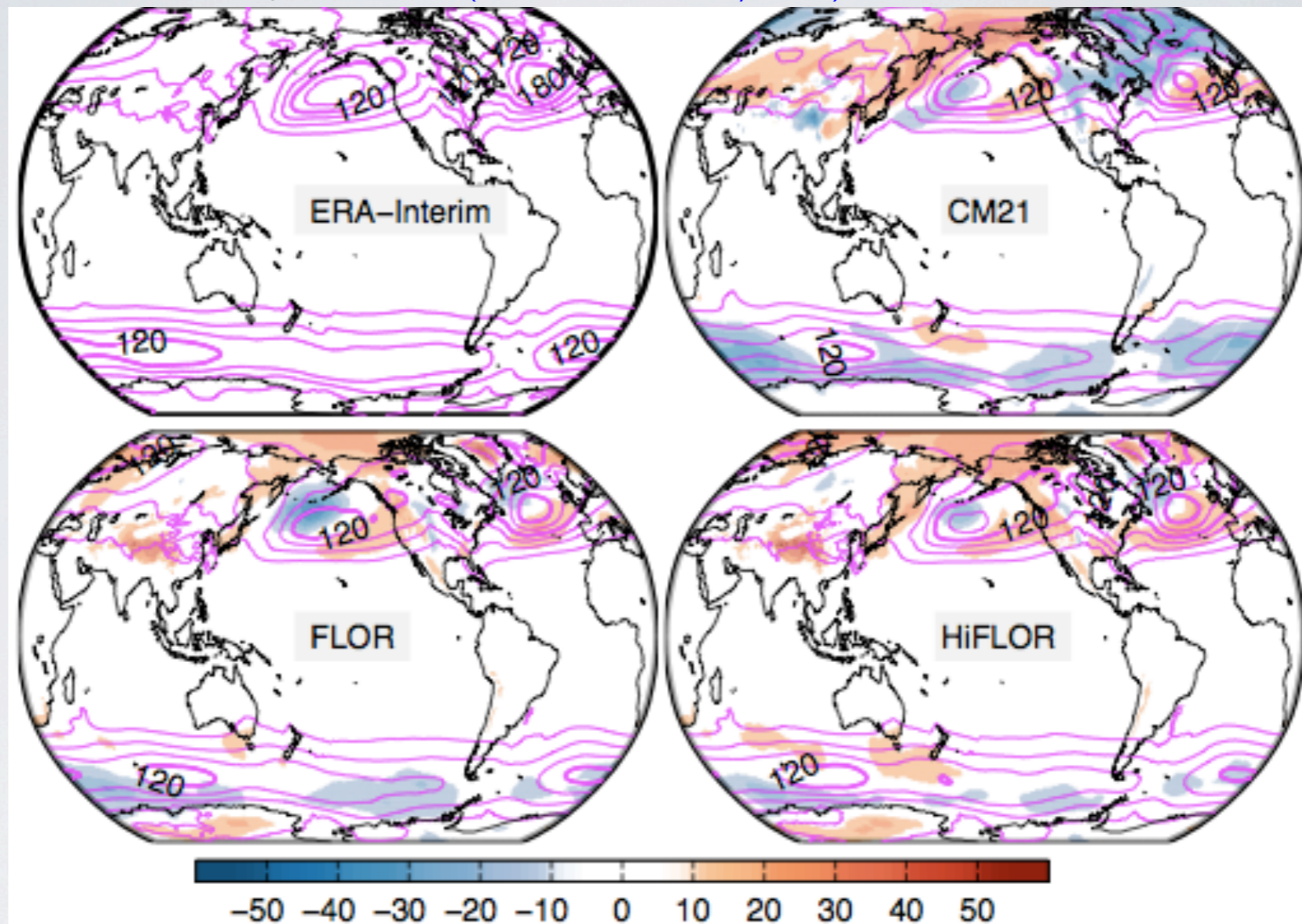
# I-July Initialized Retrospective NA TC forecasts with HiFLOR (25km FV3 atmosphere coupled to 1° MOM5)



Prediction of TCs

# Model fidelity of ETS: Can we do it better using high-res?

DJF ETS: Var(filtered 6-hourly SLP)



Contour: ETS climatology; Shaded: Model bias

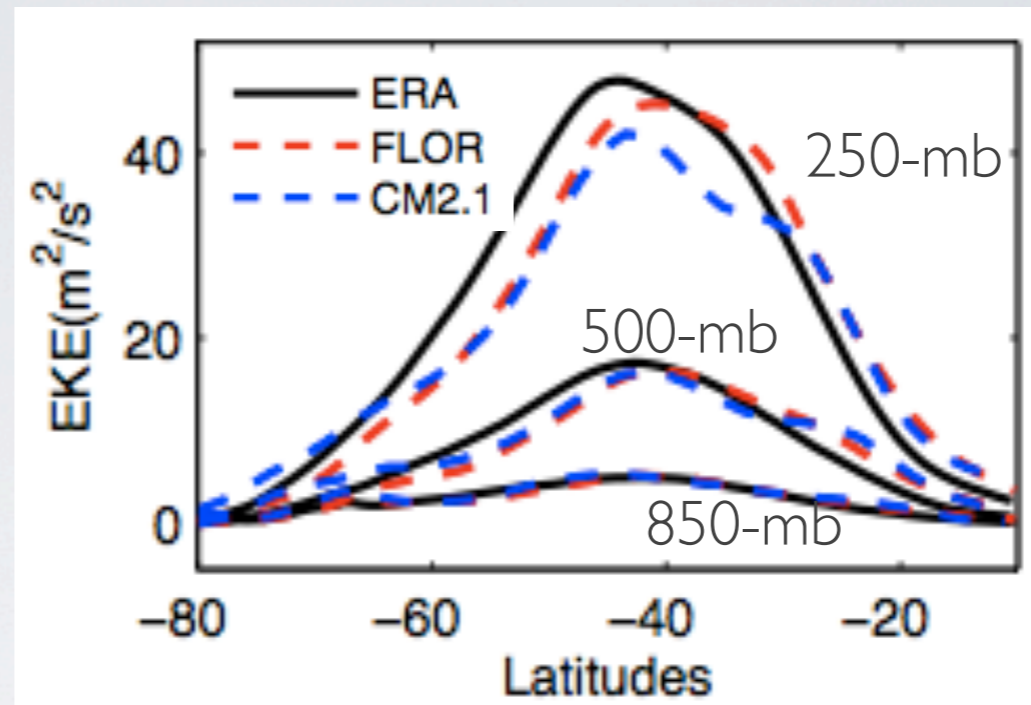
FLOR/HiFLOR improves climatological ETS over North America, North Atlantic, Eurasia and Southern Ocean.

# Model fidelity of ETS: mean and variations of eddy kinetic energy (EKE) simulated by high-res coupled models

SH baroclinic annular mode (BAM)  
(Thompson and Barnes, 2014):

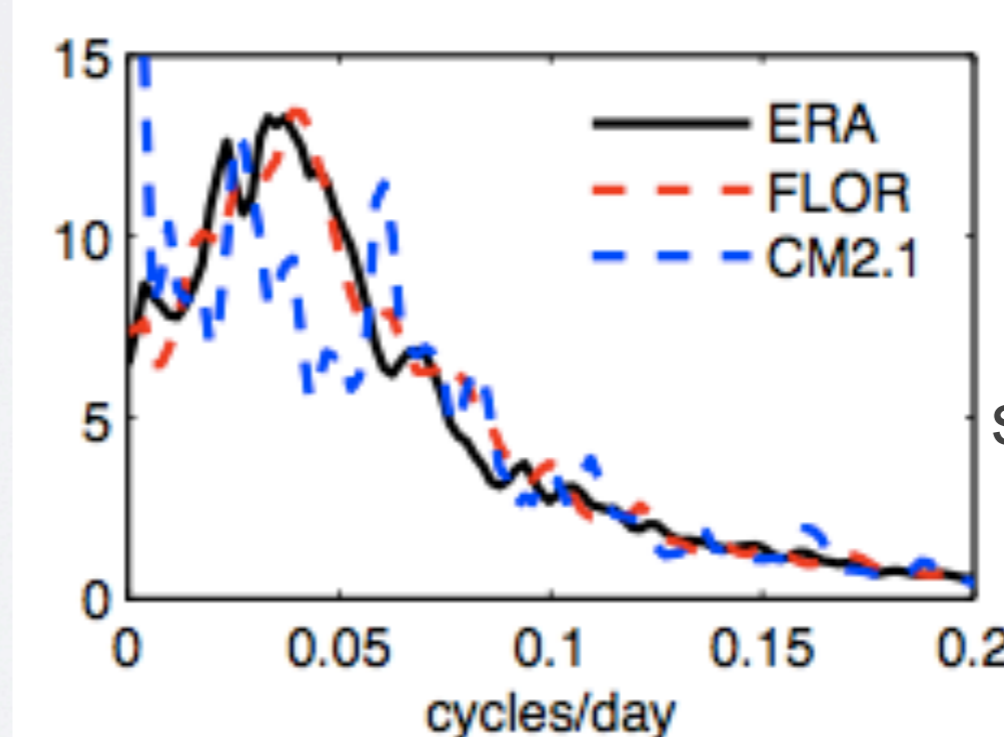
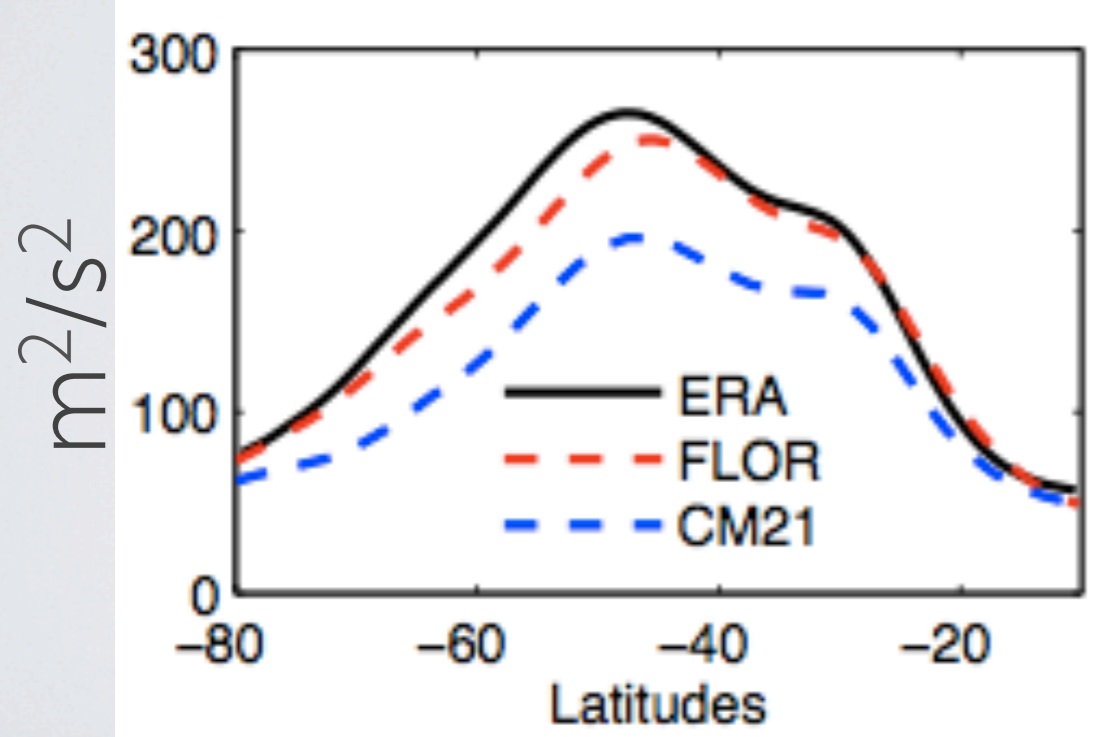
- Leading EOF mode of daily EKE
  - Periodicity of 20-30 days

## Subseasonal signal



Leading EOF  
daily EKE

Mean EKE at 250 mb



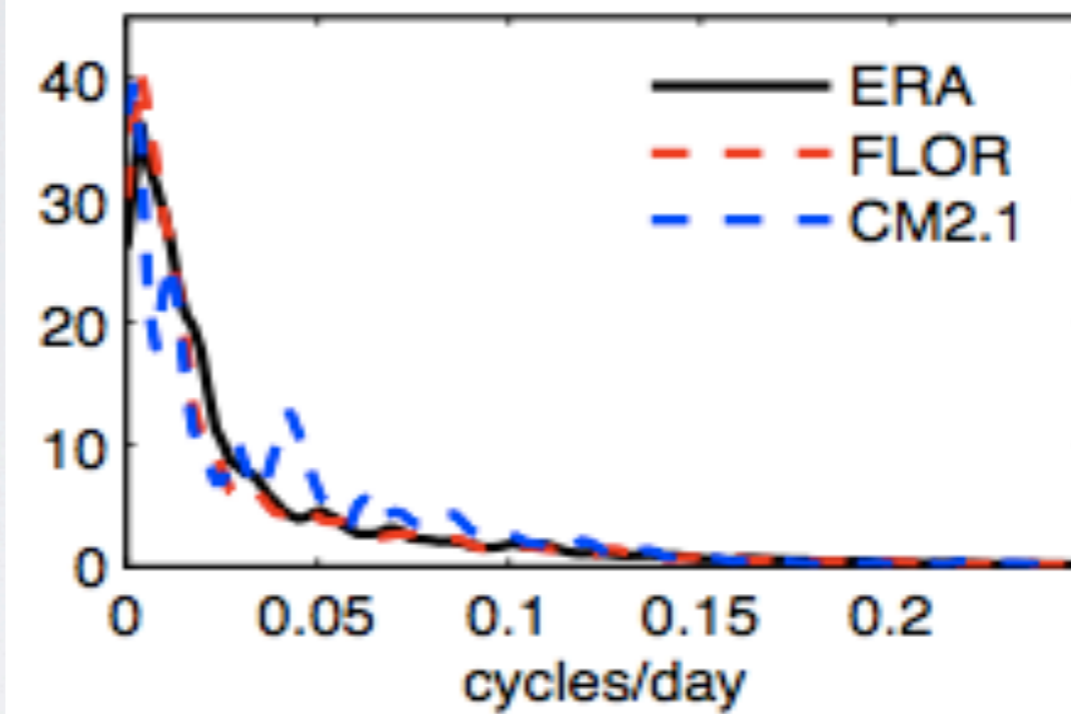
BAM  
spectrum

FLOR (1990-control) improves climatological SH EKE as well as spatial-temporal variations.

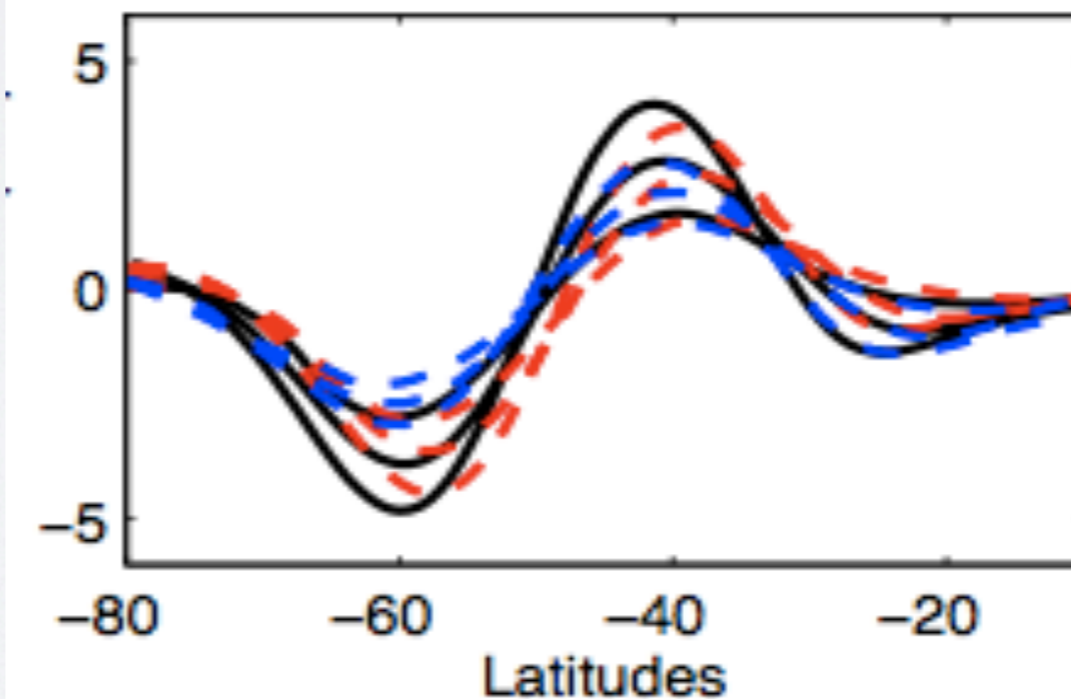
# Model fidelity of ETS: mean and variations of zonal mean zonal winds simulated by high-res coupled models

SH barotropic annular mode (SAM)  
(Thompson and Barnes, 2014):

- Leading EOF of daily zonal-mean U
  - Dipole pattern
  - Red-noise-like spectrum



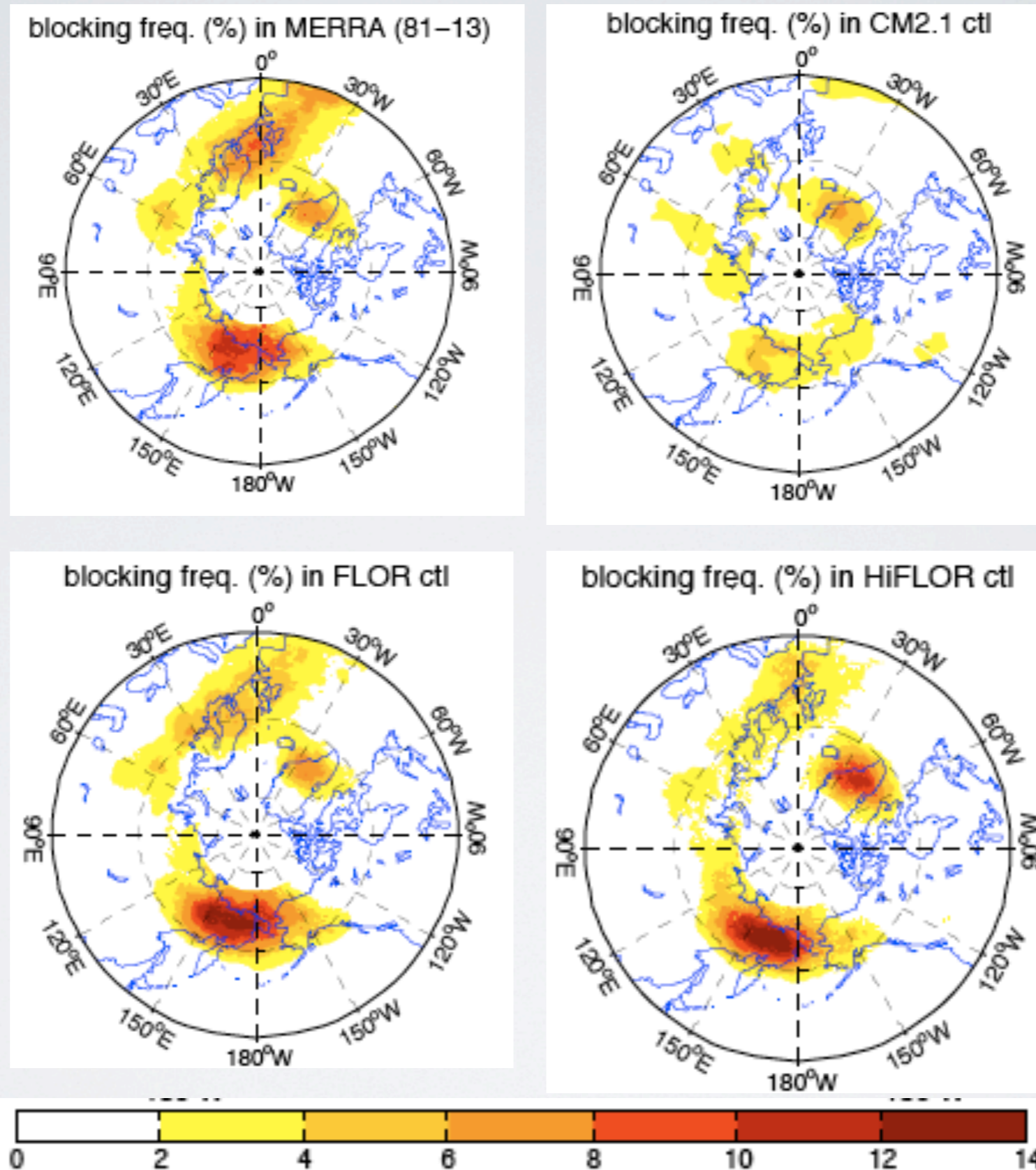
SAM  
spectrum



Leading EOF  
Daily U bar  
250, 500, 850

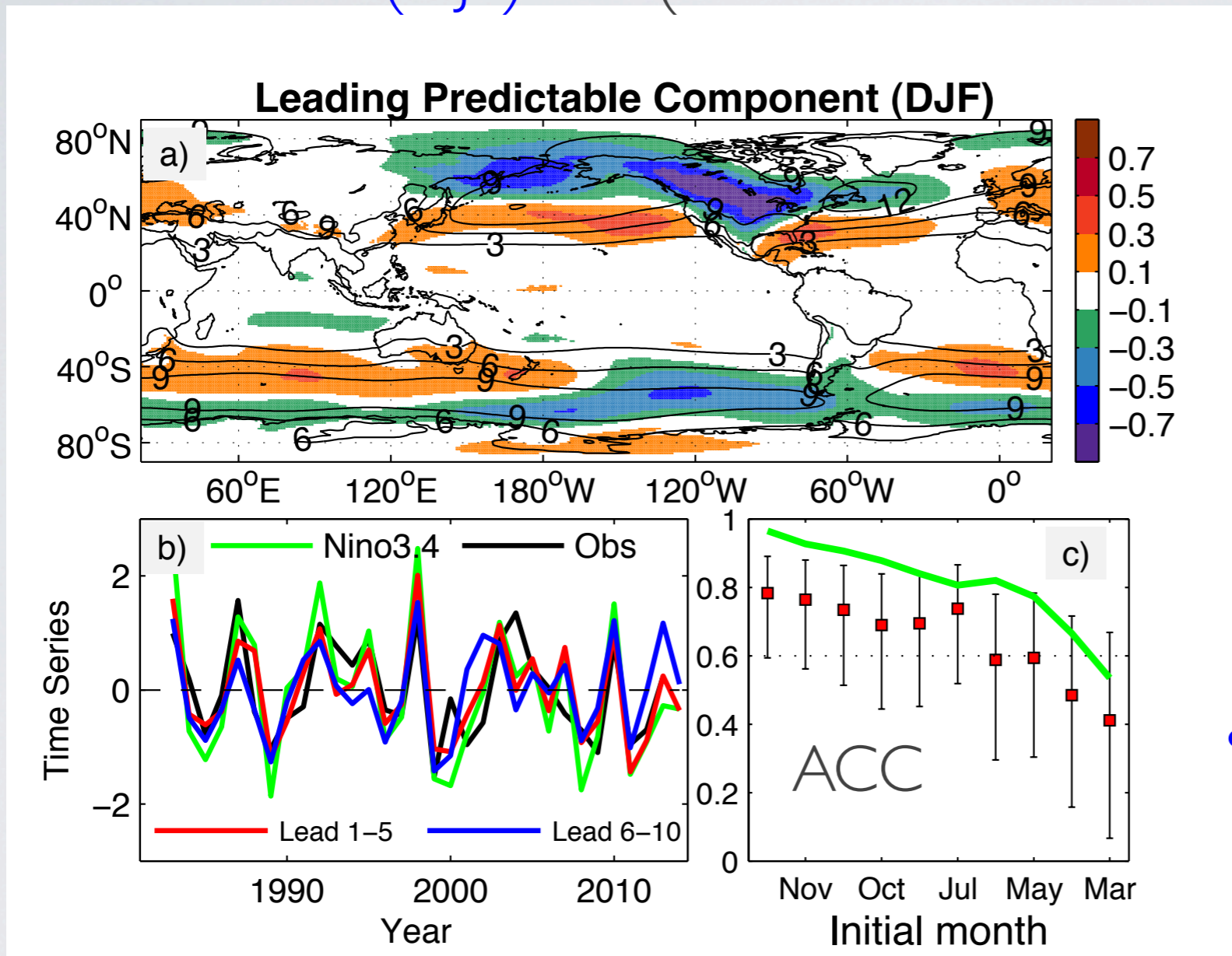
FLOR (1990-control) improves the spatial-temporal variations of SAM.

# Model fidelity of ETS: blocking frequency



ETS predictability: Leading Predictable pattern of storm tracks is ENSO-related, and is predictable up to 9 month lead time.

Storm track (DJF) : std(24-hour difference filtered SLP)

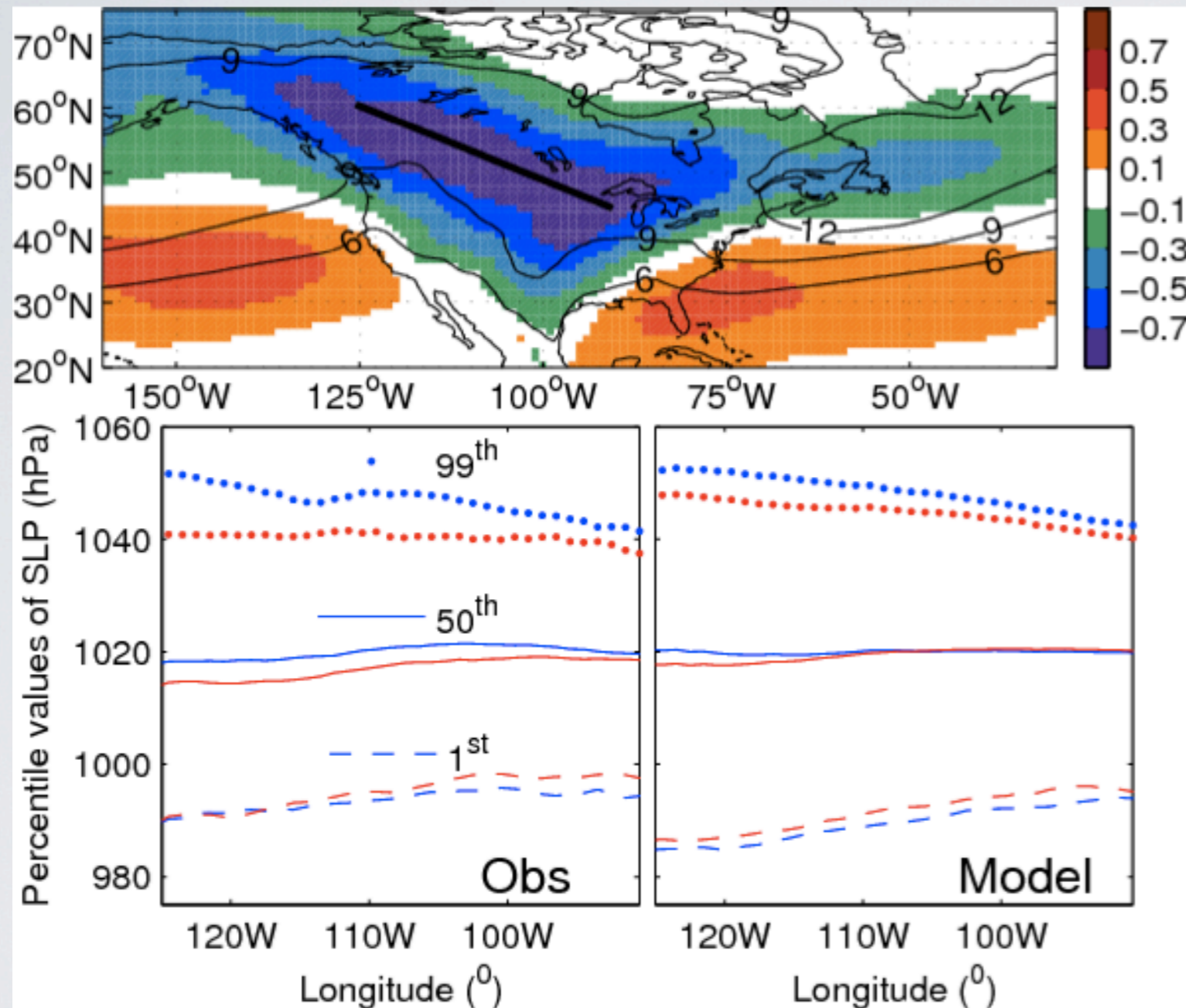


- Storm reduction over most North America
- Time series highly correlated with NINO3.4
- Skill is comparable with predicting ENSO

FLOR

Yang et al. (2015, J. Clim.)

# ETS prediction: The model could predict the storm extreme changes associated with ENSO



During **El Niño** years:

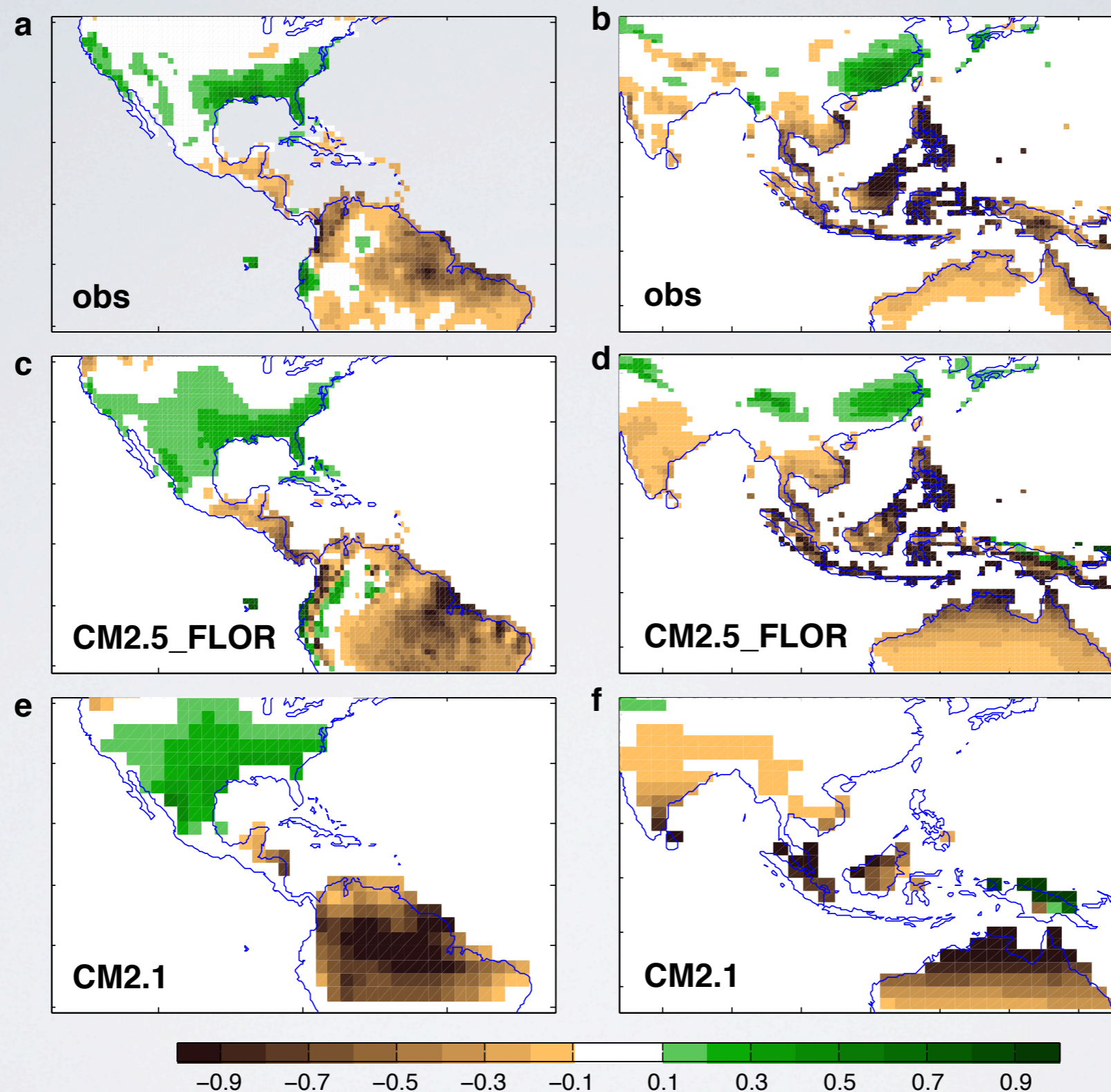
Reduced storm tracks →  
Reduced both anticyclones and  
cyclones → Smaller 99<sup>th</sup>  
percentile value and larger 1<sup>st</sup>  
percentile value (Narrower  
distribution width)

Vice versa for **La Niña** years

Model agrees well with Obs

Blue: **La Niña** composite Red: **El Niño** composite

# ENSO rainfall pattern improved in FLOR (prediction skill up too)



Most predictable precip pattern (mm/day) (Jia et al. 2015, J. Clim.)

# Summary

- Does high-res improve model fidelity in terms of TCs and ETSs?

Yes. Improved model fidelity of TCs (TC-resolving (50km) , TC-category-resolving(25km) ) and ETSs (Intensity, EKE, intrinsic modes (SAM, BAM), blocking )

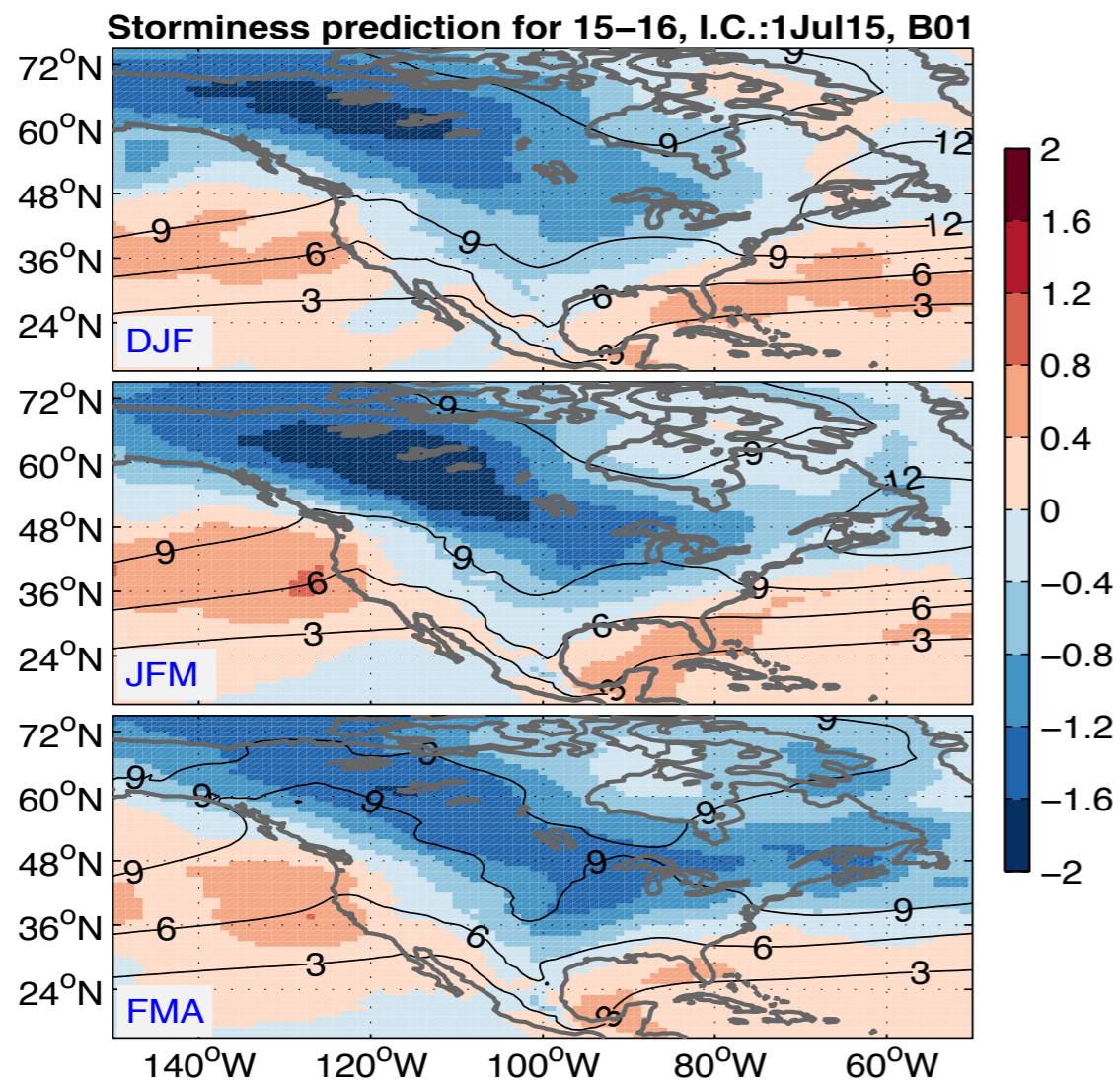
- Does high-res improve prediction of TCs and ETSs?

Yes. Skillful seasonal prediction of TCs (regional, category) and ETSs.

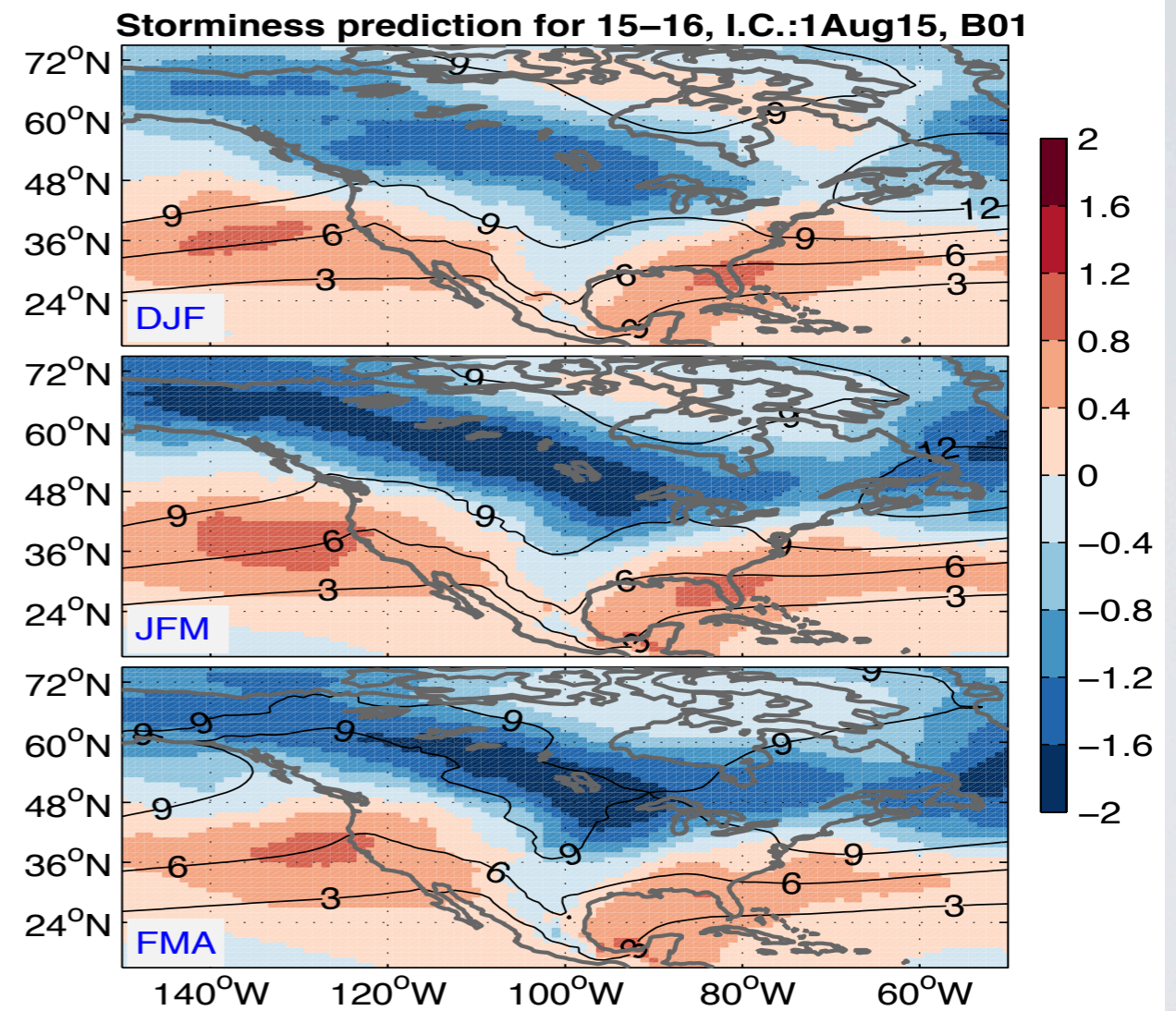
- Skillful seasonal predictions of TC activity and ETS activity at regional scales appear feasible

# Experimental prediction of 2015-16 winter ETS over North America using GFDL-FLOR

Forecast: 1Jul2015



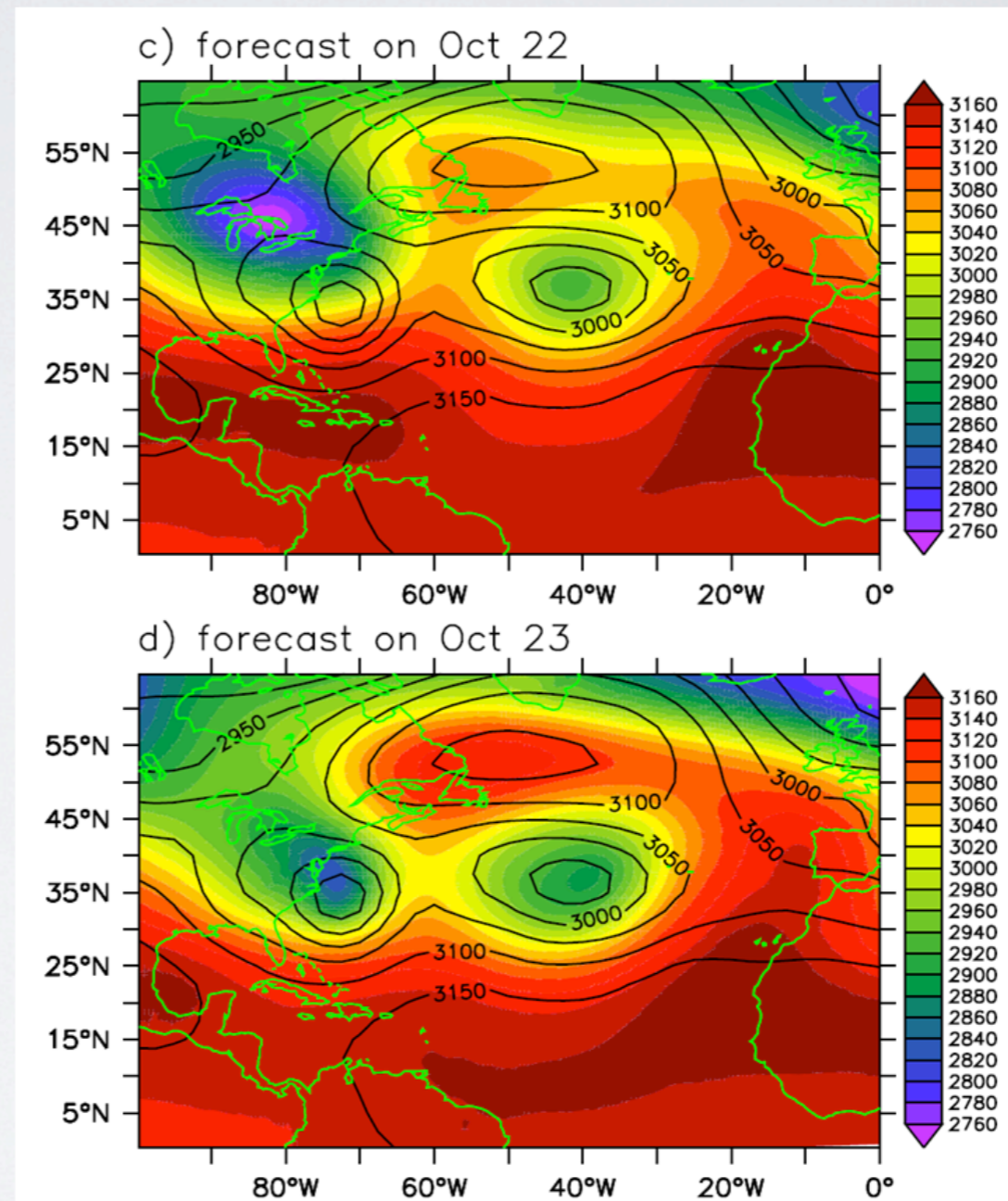
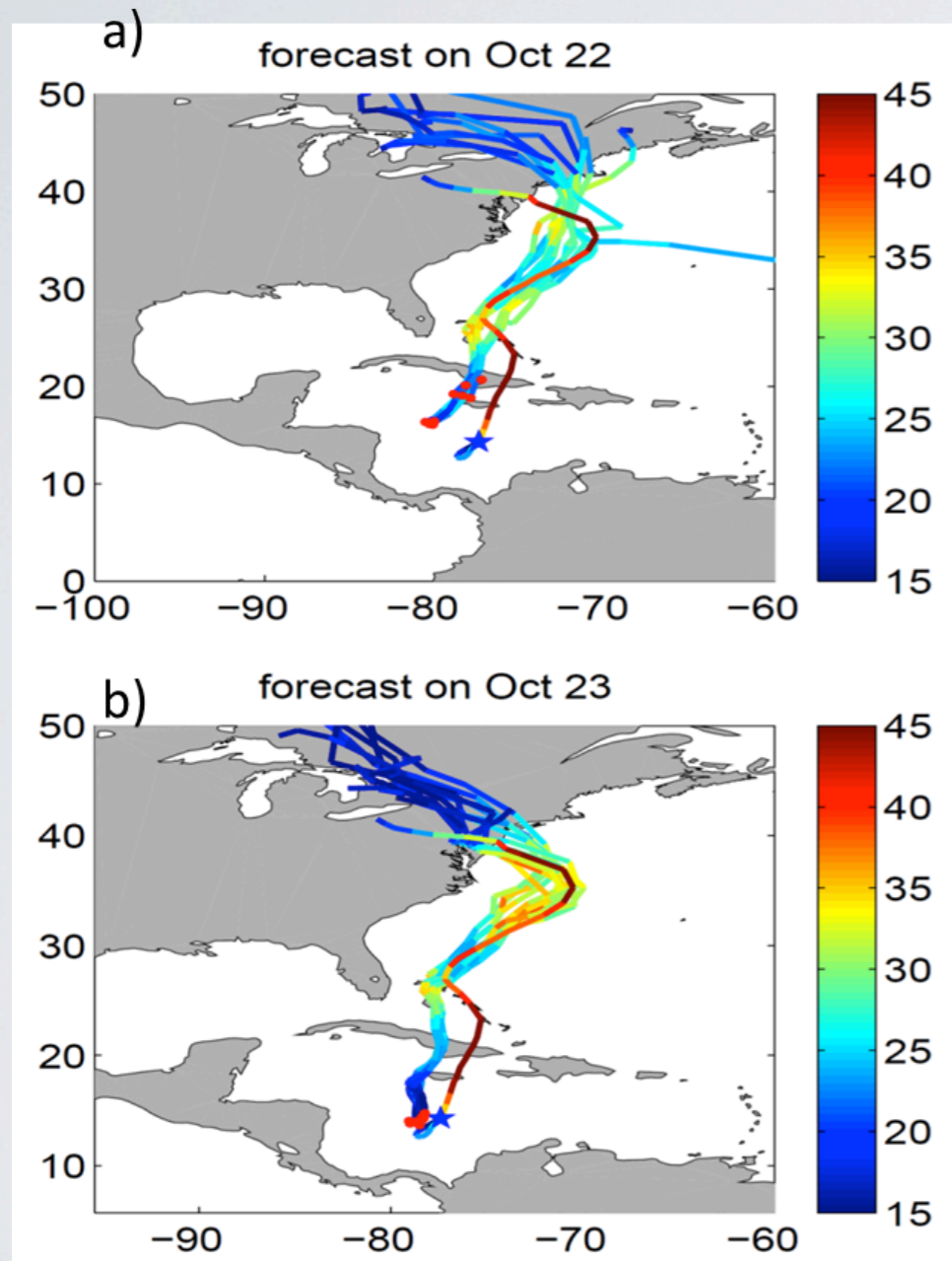
Forecast: 1Aug2015



Reduced storms: Mid-USA, Northeast of USA and Canada  
Increased storms: Southeast, Southwest of USA

THANKS

# Seamless predictions: 5-7 days forecasts of Sandy with a version of FLOR



*Xiang et al.  
(2015, MWR)*

Forecasts initialized 7 & 8 days before landfall capture track